ON THE CONTROL OF DESTRUCTIVE INSECTS IN THE HERBARIUM

E. D. Merrill

One problem with which most curators of herbaria are concerned is the protection of the collections under their charge against the depredations of destructive insects. The chief offender is the cigarette or tobacco beetle, known in botanical circles as the herbarium beetle, *Lasioderma serricorne* (Fabr.). There are other offenders such as the drug-store beetle, *Stegobium paniceum* (Linn.), but the *Lasioderma* is the most common one. Whatever means prove to be effective in controlling or eliminating the distinctly serious herbarium beetle, will, in general, apply to all other insects that are destructive to stored botanical specimens.

Lasioderma serricorne (Fabr.) is of cosmopolitan distribution, infesting tobacco wherever it is stored. Regarding it, Mallis* says: "The foods upon which it feeds are legion, and a few of these are rice, ginger, raisins, pepper, dried fish, dates, belladonna, drugs, seeds, and pyrethrum powder. They like older tobaccos apparently because they possess a strong odor." Apparently cured tobacco is its most favored food, or at least one of its most favored ones. The life history of the insect is completed in from 70 to 90 days. In temperate climates the insects swarm first in May and again in August. In some parts of the United States there may be three generations in a year; in tropical regions there are as many as five or six overlapping generations within a year. In the humid tropics and even in the warm humid parts of the southeastern United States destruction of herbarium material by these insects is much greater than in cooler regions. However, in heated buildings it is surmised that breeding may take place throughout the year, as is the case in the tropics. The eggs hatch in from six to ten days. The larval stage lasts from five to ten weeks; it is in this stage that herbarium specimens are damaged. At temperatures of about 60° F. the larvae become dormant and may then hibernate. The prepupal and pupal stages last from two to three weeks. Adult beetles may live from three to four weeks. This brief outline is given because of its importance in reference to control by fumigation or by other means. Single fumigations at long intervals are ineffective.

In herbarium practice, from a historical standpoint, controls have taken the form of tight cabinets, sometimes difficult to attain when wood is used, as is generally the case; by actual poisoning of the specimens; and by fumigation. In some institutions repellents are used to a certain degree. Any experienced curator will realize that such controls are only in part effective, for there is always the human element to consider. To keep any

* **Mallis, A.** Handbook of pest control. 340. 1945.

herbarium free from the depredations of the herbarium beetle and other destructive insect pests involves constant attention. Not infrequently, in little consulted material, the actual destruction of important specimens may reach distinctly large proportions before an infestation is detected.

In earlier years arsenic was effectively utilized, but its use has long since been abandoned because it is a cumulative poison, and in too many cases arsenic poisoning developed among herbarium workers because of their exposure to arsenic dust. Today the most generally used poison is a saturated alcoholic solution of corrosive sublimate to which phenol is sometimes added. This is a very poisonous mixture and has to be handled with great discretion; mercury is also a cumulative poison. It is a well known fact that even when specimens are dipped in the solution and redried before mounting; or when the mounted specimens are sprayed with the solution, or it be painted over the material with a soft brush, permanent protection is not attained. In the course of time the corrosive sublimate becomes inert. When this happens fumigation and repoisoning are necessary. The treatment is expensive in time and in material, and cannot be considered as efficient. Not infrequently specimens that have been thoroughly poisoned with corrosive sublimate are utterly destroyed by the herbarium beetle. Unfortunately, when specimens are poisoned it may give responsible curators a false sense of security.

At the Gray Herbarium and at the Arnold Arboretum specimens are not poisoned, dependence being placed on tight steel cases combined with fumigation when necessary. The first tight steel cases in botanical history was the beginning of the extensive installation of excellently designed ones at the Gray Herbarium in 1905, followed by the Arnold Arboretum installation in 1908–09. Since the first installation of steel cases in Cambridge the use of them has been greatly extended, but as yet in the majority of the large herbaria of the world dependence is still placed on wooden cases, which, unfortunately, are not always too tight.

It is, in some herbaria, standard practice to fumigate all cases at least once each year. Theoretically with modern tight steel cases, an herbarium should be reasonably free from infestation by the herbarium beetle and similar pests; practically this is not the case for by one means or another gravid female beetles will gain access to stored material; naturally the case doors have to be opened very frequently, and sometimes, through carelessness, they may remain open for relatively long periods of time. With unpoisoned or even poisoned material in storage in the cases this is an invitation to future trouble.

The basic installation at the Arnold Arboretum is represented by an extensive series of modern steel cases. As noted above none of the specimens are poisoned. A decade ago the herbarium beetle infestation here was very extensive throughout the building, mature beetles, pupae and larvae occurring in great abundance in all parts of the large collection; and this in spite of the fact that a few years earlier the entire building had been closed, sealed as tightly as possible, and fumigated with hydrocyanic

acid gas. The situation in 1936 was so critical and destruction so great that one large room was sealed and refumigated with hydrocyanic acid gas. All of the steel cases were fumigated individually, and this fumigation was repeated several times. Through this fumigation campaign naturally not all of the viable eggs, larvae, pupae, and mature beetles were destroyed, but the number of insects was very greatly reduced.

Realizing that fumigation alone, unless repeated at frequent intervals, was not to be depended upon, any more than when all specimens were poisoned with the corrosive sublimate solution, repellents in the form of naphthalene flakes and paradichlorobenzene were placed in each case. In the steel cases this mixture, about two thirds naphthalene and one third paradichlorobenzene was placed in muslin bags, a bag reasonably full of the mixture placed in each case, in an upper pigeon-hole. For the cartons* (and actually in excess of 3,000 of these are now in use for temporary storage of both mounted and unmounted material) a paper flap was pasted on the bottom near the back of each carton, under which was placed a large handful of the repellent. It has been current practice to renew the repellent once each year. It is admitted that the use of these substances may be objectionable for occasionally an individual may be allergic to one or both of them; yet with the cases closed the odor in the building is never strong, and is normally in no way objectionable. In fact the odor is scarcely noticeable at any time except near a recently opened case.

There is, of course, always the chance of reinfestation of stored collections even if the specimens be poisoned, even if the cases are tight, and even if repellents are used. Naturally the combined naphthalene-paradichlorobenzene fumes within the cases are not in sufficient concentration to be lethal to either the eggs, the larvae, the pupae, or the adult insects. It is, however, a manifest fact that the odor is very objectionable to the insects and that the gravid female will always choose unprotected material as a place for depositing her eggs, if there be any choice.

It is not claimed that the extensive fumigation campaign in 1936–37 destroyed all of the thousands of herbarium beetles that at that time thoroughly infested the reference collections at the Arnold Arboretum. With large collections of incoming material constantly being received from all parts of the world there was always the chance of reinfestation. As a matter of fact the greatest danger of reinfestation is returned in loans from other institutions, and duplicate material received from such institutions as exchanges. In some recently returned loans the destruction of the specimens while away for study purposes was so great that some drastic step seemed to be called for. For the present this has merely taken the form of a sticker, printed in red ink and attached to all outgoing loan forms, reading:

"Important Notice

In recent years we have had the sad experience of finding that certain returned loans of important historical botanical material were badly in-

* **Merrill, E. D.** An economical herbarium case. Torreya **26**: 50–54, *fig. 1–2*. 1926.

fested with herbarium beetles. In one particular case the essential parts of many important specimens were utterly destroyed during the time the material was on loan, reducing their value to a minimum. Please safeguard this loan against the ravages of herbarium beetles throughout the period of the loan by the liberal use of insect repellents such as naphthalene or paradichlorobenzene. *These specimens have not been poisoned and hence are particularly subject to the ravages of herbarium pests.*"

Our actual loans within the past decade have varied from a minimum of about 1000 to a maximum of 4000 or an average of about 2500 mounted sheets per year. All material borrowed from other institutions for study purposes, and these borrowings averaged 3000 per year during the past decade, is fumigated immediately on receipt of a shipment. In the decade the total receipt of specimens from all sources, including duplicates, approximate 430,000 to which may be added about 65,000 sheets in the form of borrowed specimens and returned loans, or a grand total of nearly 500,000 specimens, all to be considered as potential sources of reinfestation of our herbarium by the herbarium beetle.

In current practice all incoming material is thoroughly fumigated, whether this consists of new collections as received from the field, exchanges from other institutions, purchased material, borrowed sheets and returned loans. All material, as mounted, is placed in tight cases well supplied with the repellent. Even before a distribution into the herbarium such material, after being placed in family arrangement, is refumigated. Such steps have been considered to be necessary to avoid adding infested specimens to the reference collections. Special care has been taken to see that the doors of all cases be kept tightly shut except as it was necessary to open them when material was being studied, removed, or added. A study collection taken out even for a period of only a few weeks, is always fumigated before the specimens are returned to permanent storage.

It is now about eight years, since these regulations went into full force. In that period no staff member, visiting botanists or students have reported seeing live beetles, larvae, or pupae in the building. This is, indeed, a very striking contrast to a decade ago when the infestation was very great; so great that one could find quantities of live beetles, larvae, and pupae, more or less embedded in the strips of felt against which the doors of the steel cases close. In this period the number of staff members who use herbarium material all or a part of their time has varied from the neighborhood of eight to ten individuals; and this takes no account of scores of visiting botanists and students who have consulted our material. All investigators were requested to watch for signs of insect damage and for live insects, and if any of the latter were observed, to report the matter at once; there have been no reports of infestation in the period covered. The herbarium now contains approximately 700,000 mounted sheets, with many additional thousands of unmounted specimens in storage, with vast collections of undistributed duplicate material of one type or another. None of the specimens is poisoned. Considering the tremendous infestation of a

decade ago, and the situation that still exists in certain other large herbaria, this is indeed a remarkable record.

It is a well known fact that the herbarium beetle is very selective. Entire families of plants are more or less immune to their attacks, although it is admitted that they will destroy flowers of most species in most families, as well as soft fruits and soft vegetative parts. Curiously the Gramineae, which yields most of the forage on which herbiverous mammals subsist, are, in general, free from the depredations of the herbarium beetle except in those genera which have pithy stems more or less charged with sugar or starch, such as *Zea*, *Saccharum*, and allied genera. Another monocotyledonous group that is also remarkably free from their depredations is the Cyperaceae. In those families having sclerophyllous or leathery tough leaves, such as most of the Coniferae, the Palmae, as to their leaves, the Myrtaceae, the Lauraceae, the Guttiferae, many genera of the Ericaceae, and numerous other families, damage is normally slight except to the flowers. In the tropics, even when all material had been poisoned with the corrosive sublimate solution, I have noticed serious damage even to the sedges and some grasses, as well as to the ferns and fern allies, mosses, and lichens. One may assume that no single natural group of plants is wholly immune to attack. Certain it is that the flowers of all or most species are vulnerable.

Generally speaking certain natural families of flowering plants are peculiarly susceptible to damage or destruction by herbarium insects. Whether or not the gravid females are attracted by certain odors is not known, but it is suspected that this is the case. It is a well known fact that stored herbarium material in certain families is characterized by distinctive odors, such as the Caprifoliaceae, Umbelliferae, Araliaceae, Labiatae, Compositae, etc. all highly susceptible groups. However, distinctive odors are not in general associated with material representing other preferred families such as the Solanaceae, Scrophulariaceae, Capparidaceae, Cruciferae, Asclepiadaceae, Apocynaceae, Moringaceae, Tropaeolaceae, Papavaraceae, Ranunculaceae, Nymphaeaceae, Liliaceae, Araceae, and certain genera of the Leguminosae and Rosaceae, all groups that are especially attractive to the herbarium beetle larvae. It is to be noted that the majority of the species in most, but not all, of these families are predominantly herbaceous. It seems highly probable that the gravid female insects may be attracted by certain glucosides, alkaloids, or food elements in representatives of the above families, as well as by distinctive odors. Whatever the attraction is, it is clear that the families listed above are the preferred ones, and stored specimens representing them are those most frequently damaged or even destroyed by these herbarium pests. It may be noted that the same elements (glucosides) which give the characteristic taste to most representatives of the Cruciferae, occur also in the Tropaeolaceae and the Moringaceae; all or most of the representatives of these three families of plants are peculiarly susceptible to attack by the herbarium beetle. Usually it is largely the flowers and the tender leaves that

are destroyed; but in unprotected Umbelliferae often the whole plant is devoured, even the somewhat lignified stems of certain species. At any rate an experienced and observant curator can cite cases of utter destruction of important material in such families as those above listed through the unchecked ravages of active and rapidly increasing colonies of herbarium beetles.

This selectiveness of the gravid females as to preferred food plants gave me an idea which I put into practice following the last comprehensive fumigation of our herbarium cases nine years ago. A selection was made from common species to which the herbarium beetle is notedly partial, such as *Asclepias*, *Apocynum*, representatives of the milky Compositae such as *Sonchus* and *Taraxacum*, and selected genera in the Solanaceae (including *Nicotiana*), Umbelliferae, Cruciferae, Papaveraceae, Labiatae, and Scrophulariaceae. Wherever possible selection was made on the basis of tenderness of vegetative parts and abundance of flowers. Quantities of roughly dried herbarium specimens were prepared. This material was placed loose on specimen sheets and tied in unwrapped bundles about six inches thick. Twelve of these bundles of preferred plants, "bug traps" if you wish, were numbered, dated, and placed in strategic places in all rooms where herbarium material was stored or handled. About four times each year these "bug traps" are picked up, fumigated, redated, and returned to their positions in the building. The evidence is that, following fumigation, the use of repellents, plus the installation of the "bug traps," is what has kept a once very badly infested, large herbarium, and one in which none of the specimens are poisoned, entirely free (as far as our observations go) from infestations of the herbarium beetle for a period of eight years. In that period the only material that has suffered has been that loaned to specialists in other institutions for study purposes.

There is another group of much smaller insects which are destructive in a limited sense, which many curators overlook or perhaps ignore. These are the so-called book lice, representatives of the Psocidae, which thrive on pollen, even when the specimens have been poisoned by corrosive sublimate. Thus it is that pollen experts, turning to this or that herbarium for material, are sometimes disappointed by discovering that these nefarious little insects have anticipated them by destroying all of the pollen grains in both open and unopened anthers. They are controlled even easier than the herbarium beetle by the use of repellents. It is possible that certain Thysanoptera do a certain amount of damage to stored herbarium material on occasion, especially where the humidity is high. These, and all other insects which thrive on dried herbarium specimens are easily controlled by the simple methods outlined above.

It is admitted that the installation of "bug traps" which I advocate, may be a potential source of reinfestation of stored herbarium material, whether this be poisoned or unpoisoned. There is thus a certain human element in the picture. However, if all the "bug traps" be picked up at regular intervals, a minimum of four times a year at three months inter-

vals, and thoroughly fumigated before they are replaced, there is no danger. In practice it would doubtless be advisable to replace the material that make up the "bug traps" occasionally; here this has been done only once since the first installation was made eight years ago.

I believe that our experience over a decade, with not a single live beetle, pupa, or grub reported in the last eight years, rather definitely demonstrates the efficacy of this very simple and relatively inexpensive method of eliminating these herbarium pests. The scheme is practicable, efficient, and what is more, inexpensive; in fact much less expensive in time and in material than the current practice, in some large herbaria, of poisoning all material with corrosive sublimate before the mounted sheets are distributed into the herbarium, to say nothing of repeated fumigations. Perhaps the very simplicity of the plan will militate against its general use, but definitely it is worth a thorough trial. About the only chances of reinfestation, once a herbarium is free from these destructive pests, would be to forget to renew the repellent in the cases (this should be done once a year), to forget to pick up and fumigate all the "bug traps" at proper intervals (once in about three months); to fail to fumigate all incoming material, including exchanges, recently collected material coming in from the field, borrowed material, and returned loans. A potent source of reinfestation is material that has been exposed in institutions where it is known that bad infestations exist, including exchanges, loans, and borrowed specimens. Admittedly my observations are based entirely on empiricism, i.e., observation; but never-the-less the simple scheme works. I unhesitatingly recommend it to all curators of herbaria who are faced with the really serious problem of protecting their collections against the ravages of destructive insects.

From our experience it is not necessary to look upon the presence of from few to many of these destructive insects in any herbarium as a necessary evil and one that cannot be avoided. It has been demonstrated, through our experience over a decade, that the herbarium beetle and other secondary herbarium pests can be thoroughly and economically controlled by the simple method outlined above, and this without the use of poison, or poisonous gases other than the desirable preliminary fumigations. Not one of our numerous steel cases has been fumigated in eight years, or since the "bug traps" were installed; and no infestations have been discovered in the thousands of cartons now in use. The entire herbarium, consisting of approximately 700,000 mounted sheets, none of the material poisoned with corrosive sublimate, is now free from infestation, and it is anticipated that it will remain free as long as the present practice of fumigation of all incoming material, free use of repellents, and the maintaining of "bug traps" with their fumigation at regular intervals, is followed.

Father Hugh O'Neill* has demonstrated the fact that heat may be efficiently used in the control of herbarium pests. If the temperature be raised to 140° F. (60° C.) this is sufficient to kill insects in all stages of

* **O'Neill, H.** Heat as an insecticide in the herbarium. Rhodora 40: 1–4. *1 fig.* 1938.

development and within a few minutes. Because of the nature of the stored material it takes four or five hours at a temperature of 170° F. (77° C.) to attain this end, as paper is a poor conductor of heat and of course it is necessary to raise the temperature in the center of the bundles to that required for lethal purposes. Most institutions are not equipped to apply this heat treatment, although at the University of Montreal each storage case is equipped with an electrical heating unit. The use of a partial vacuum is very effective in killing insects. Here the initial installation is expensive, and because the bulky herbarium material must be transported to and from the vacuum chamber, the labor costs are high; this same statement applies when herbarium material must be transported to a heat equipped unit.

It is believed that some of the modern insecticides such as DDT may prove to be very efficient either sprayed over the specimens or merely sprayed over the interior surface of the storage units. Father O'Neill reports to me that with sprayed specimens difficulties may develop, for certain individuals are allergic to DDT dust. In one case that he mentioned the difficulties were so great that spraying of specimens has been discontinued and now dependence is placed on spraying the interior of the storage units. Perhaps this spraying of the interior surfaces of the pigeon holes occasionally may suffice; at any rate it is distinctly worth a thorough trial. We do know from our own experience over the past decade that the combination of fumigation, use of repellants, and the installation of "bug traps" is very effective.

I have noted above that there is always the human element to be considered. Unless curators assume their proper responsibilities and keep constantly on the alert for indications of the presence of the herbarium beetles, no matter what system be followed reinfestation may occur at any time during the breeding season of the insects involved. Proper precautions and eternal vigilance on the part of responsible officials is the price that an insect free herbarium exacts. The cooperation of all staff members and of others who have occasion to consult stored material is important, and this whether the specimens be poisoned or not. Whether an infestation be light or severe, it should be attended to immediately once it is discovered. To delay in applying control methods is merely to invite disaster in the form of the destruction of often very valuable and utterly irreplaceable specimens.

ARNOLD ARBORETUM,
HARVARD UNIVERSITY.